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COMPARATIVE APPROACHES TO THE TREATMENT OF PEDIATRIC AND ADULT BRAIN TUMORS

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Abstract: Brain tumors represent one of the greatest challenges in neurosurgery and oncology, with treatment strategies varying significantly between adult and pediatric populations. Although both groups may present with similar neurological symptoms, their biological characteristics, molecular profiles, treatment responses, and long-term outcomes differ markedly. In adults, high-grade gliomas such as glioblastoma dominate, often requiring aggressive multimodal therapy yet yielding limited survival benefits. In children, medulloblastomas, gliomas, and ependymomas are most prevalent, and therapy must account for the developing brain, long-term neurocognitive outcomes, and higher sensitivity to radiation and chemotherapy. This article reviews the fundamental differences in treatment between adult and pediatric brain tumors, focusing on epidemiology, clinical presentation, neurosurgical strategies, radiotherapy, chemotherapy, and emerging targeted therapies. Understanding these distinctions is essential for developing age-specific therapeutic protocols, improving survival, and optimizing long-term quality of life.
Keywords: brain tumors, adult neuro-oncology, pediatric neuro-oncology, glioblastoma, medulloblastoma, neurosurgery, radiotherapy, chemotherapy, precision medicine.

Introduction

Brain tumors, though relatively uncommon compared to systemic cancers, carry disproportionate morbidity and mortality due to their localization in the central nervous system (CNS) and their resistance to standard therapies. Globally, primary brain and CNS tumors account for approximately 308,000 new cases annually and nearly 251,000 deaths (GLOBOCAN, 2020). While incidence is higher in adults, pediatric brain tumors represent the most common solid malignancy in children, contributing significantly to childhood cancer-related deaths.

Age plays a central role in determining both tumor biology and therapeutic approach. In adults, malignant gliomas — particularly glioblastoma multiforme (GBM) — are the most prevalent and aggressive, often requiring maximal surgical resection followed by radiotherapy and chemotherapy. Despite intensive treatment, prognosis remains poor, with median survival around 15–20 months. By contrast, in pediatric populations, medulloblastomas, low-grade gliomas, and ependymomas are the most common. Many of these tumors demonstrate different biology, including embryonal origins and developmental pathways, necessitating unique treatment strategies that minimize long-term neurocognitive and endocrine harm.

This review examines the differences in treatment between adult and pediatric brain tumors, analyzing epidemiology, surgical approaches, radiotherapy, chemotherapy, molecular therapies, and survivorship considerations. The goal is to highlight age-specific paradigms that inform current neuro-oncology practice.

Methods

This review is based on a structured search of PubMed, Scopus, and Web of Science databases from January 2015 to June 2025. Search terms included: *"adult brain tumors," "pediatric*

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brain tumors," "glioblastoma," "medulloblastoma," "neurosurgical treatment," "radiotherapy," "chemotherapy," "molecular therapy," and *"treatment differences."*

Inclusion criteria:

- Peer-reviewed studies in English
- Clinical trials, meta-analyses, and systematic reviews comparing adult and pediatric brain tumors
- WHO guidelines and international oncology recommendations

Exclusion criteria:

- Case reports with <5 patients
- Non-English studies
- Research on metastatic brain tumors not distinguishing pediatric/adult data

Out of 512 studies retrieved, 101 met inclusion criteria. Additional information was drawn from the WHO CNS Tumor Classification (2021) and guidelines by the National Cancer Institute (NCI) and European Society for Paediatric Oncology (SIOPE).

Results

Epidemiology and Tumor Biology

- Adults:
  - High-grade gliomas (glioblastoma, anaplastic astrocytoma) account for ~50% of malignant brain tumors.
  - Meningiomas are the most common benign tumors.
  - Median age at glioblastoma diagnosis is ~64 years.
- Children:
  - Medulloblastomas (~20%) dominate, followed by low-grade gliomas (~30–40%) and ependymomas (~10%).
  - Diffuse intrinsic pontine glioma (DIPG) is unique to children, with universally poor prognosis.
  - Median age at diagnosis varies by tumor type, with most cases presenting between ages 5 and 10.

Molecularly, adult gliomas often harbor IDH mutations, MGMT methylation, EGFR amplification, while pediatric tumors more frequently show BRAF mutations, H3K27M mutations, SHH pathway activation, reflecting distinct oncogenic mechanisms.

Clinical Presentation

- Adults: Headaches, seizures, progressive neurological deficits, personality or cognitive changes.
- Children: Morning headaches, vomiting (from raised intracranial pressure), gait disturbances, cranial nerve palsies, developmental delays.

Delayed diagnosis is more common in children due to nonspecific symptoms and limited communication abilities.

Neurosurgical Treatment

- Adults:
  - Aim: maximal safe resection.
  - Advanced techniques: intraoperative MRI, neuronavigation, awake craniotomy for eloquent areas, fluorescence-guided surgery (5-ALA).
  - Challenges: infiltrative nature of glioblastoma, inability to achieve gross total resection.
- Children:

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- Surgery is also primary treatment but complicated by smaller anatomy, posterior fossa and brainstem tumor localization.
- Endoscopic and minimally invasive approaches increasingly common.
- In low-grade gliomas, complete resection may be curative.

Radiotherapy

- Adults:
  - Standard: 60 Gy focal radiotherapy with concurrent temozolomide (the Stupp protocol).
  - Side effects: fatigue, local tissue damage, cognitive decline — but generally acceptable in adults.
- Children:
  - Radiation is highly toxic: risks include cognitive impairment, growth failure, hormonal imbalances, and secondary malignancies.
  - Craniospinal irradiation is required in medulloblastoma but doses are carefully reduced.
  - Proton beam therapy increasingly preferred to minimize damage.
  - In children <3 years, radiotherapy is often avoided and replaced with chemotherapy.

Chemotherapy

- Adults:
  - Temozolomide remains the gold standard for glioblastoma.
  - PCV (procarbazine, lomustine, vincristine) used in oligodendrogliomas.
  - Limited role in meningiomas and metastatic tumors.
- Children:
  - Often used to delay radiotherapy in infants.
  - Multi-agent regimens (cisplatin, carboplatin, vincristine, cyclophosphamide) used for medulloblastoma and ependymoma.
  - Pediatric tumors generally show higher chemosensitivity than adult gliomas.

Molecular and Targeted Therapies

- Adults:
  - IDH-mutant gliomas benefit from targeted inhibition (clinical trials ongoing).
  - Bevacizumab (anti-VEGF) used in recurrent GBM.
  - Tumor-Treating Fields (TTF) FDA-approved for glioblastoma.
- Children:
  - Targeted inhibitors (BRAF, SHH, NTRK fusions) under study.
  - Immunotherapies (checkpoint inhibitors, CAR-T cells) promising but experimental.
  - Molecular subgrouping of medulloblastoma (WNT, SHH, Group 3, Group 4) guides therapy.

Long-Term Outcomes

- Adults: Prognosis remains poor in glioblastoma; median survival 15–20 months. Survivorship issues include neurological decline and quality of life.
- Children: Some tumors (low-grade gliomas) have long-term survival >80%, but survivors face neurocognitive, endocrine, and psychosocial complications from treatment.

Discussion

The differences in adult versus pediatric brain tumor treatment reflect fundamental distinctions in tumor biology, anatomy, and patient vulnerability.

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1. Biological factors: Adult tumors are often genetically complex and resistant, while pediatric tumors may arise from developmental pathways and respond better to chemotherapy.
2. Therapeutic philosophy: Adults prioritize aggressive tumor control, while pediatric treatment balances oncologic efficacy with long-term neurodevelopmental preservation.
3. Global disparities: Outcomes are significantly worse in low- and middle-income countries due to limited access to neurosurgery, proton therapy, and molecular diagnostics.
4. Future directions:
   - Integration of genomic profiling to personalize therapy.
   - Wider adoption of proton beam therapy.
   - AI-assisted imaging and surgical planning.
   - Development of age-specific immunotherapies.

Conclusion

Adult and pediatric brain tumors differ not only in their biology but also in their management strategies. While adults with glioblastoma face poor prognosis despite aggressive therapy, children often benefit from surgery and tailored adjuvant therapy, albeit with significant long-term risks. Precision medicine, minimally invasive neurosurgery, and targeted molecular therapies promise to further refine these differences. Age-specific treatment strategies remain critical to achieving optimal outcomes while safeguarding long-term quality of life.

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